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AN APPLICATION OF FACTOR ANALYSIS TO A STUDY OF HUMAN ATTRIBUTES AND THEIR RELATIONSHIPS TO THE LEVEL OF PERFORMANCE OF FARM TENANTS

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The Problem and Its History

There is an increasing awareness among agricultural economists of the human factor and its importance in agriculture. Consequently, increasing emphasis is being placed on attempts to quantify this factor, more specifically referred to as management. Attempts to quantify or account for management have not been lacking, but have been largely unsatisfactory. 1/ The problem lies in measuring the influence of the management variable and in constructing an instrument measuring required abilities for predicting individual performance and behavior in farming.

1/ Attempts to account for the management factor in agricultural production have essentially used two different avenues of approach:

a. Construction of economic models free of specification bias due to omission of the management factor although the latter was not quantified explicitly. For further reference see Zvi Griliches, "Specification Bias in Estimating Production Functions", Journal of Farm Economics, Volume 39, 1957; and Yair Mundlak, "Empirical Production Functions Free of Management Bias", Journal of Farm Economics, Volume 43, 1961.

b. Construction of measures of management and subsequent use of these measures in economic analysis. The following references are selected works in this area: E. J. McCormick, R. E. Blanchard, and D. W. Thomas, An Objective Method of Selecting Farm Tenants, Purdue University, Bulletin 678, April 1959; G. A. Pond and W. W. Wilcox, "A Study of the Human Factor in Farm Management", Journal of Farm Economics, Volume 14, 1932; F. J. Reiss, "Measuring the Management Factors", Journal of Farm Economics, Volume 31, 1949; M. A. Strauss, Matching Farms and Families in the Columbia Basin Project, Washington State Agricultural Experiment Station, Bulletin 588, June 1958; W. W. Wilcox and O. G. Lloyd, The Human Factor in the Management of Indiana Farms, Purdue University, Bulletin 369, August 1932; D. G. Paris, Predicting Firm Behavior From Estimates of Input Productivity for a Sample of Western Kentucky Farms, an unpublished Ph.D. thesis, University of Kentucky, 1960; C. R. Pugh, Tenant Ability and Resource Productivity on Farms with Management Services in Indiana, an unpublished Ph.D. thesis, Purdue University, 1961.

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The first of these two approaches is one that stops short of demonstrating the handling of management as an explicit variable while the second approach tends to result in statistically insignificant management variables and measures of management that are difficult to interpret even if these measures result in a significant variable in an economic model (see C. R. Pugh, op. cit.). While the economist-statistician should not find it too difficult to construct models which are free of specification bias, a solution to the problem lies in the specification of the human input and its interrelationships.

Psychologists' endeavors along these lines have led to a considerable extension of knowledge about human behavior and the complex of problems associated with prediction of human behavior. There are no general agreements from psychological work on measured abilities, interests, attitudes, etc. of farmers as a class, except that they are a heterogenous group as far as prime attitudes are concerned. 2/

2/ Although objective data on measured attributes of potential farmers are not plentiful (see H. M. Byram and K. G. Nelson, "Guidance and Placement in Agricultural Education", Agricultural Education Magazine, 24 (2) pages 33 to 36 and 43 to 45), significant results by various workers have been obtained in this area. Nevertheless, there remain considerable contradictions among and within study areas. A report on the mental ability of farms is given by T. W. Harrell and M. S. Harrell, "Army General Classification Test Scores for Civilian Occupations", Education Psychological Measurement, 1945, pages 5 and 229 to 239. Measured interests of farmers are reported by Examiner Manual for the Kuder Preference Record, (Second edition) Chicago: Science Research Associates, 1951; Opportunities in Farming, Occupational Monograph Number 18, Chicago: Science Research Associates, 1940 and 1941. R. R. Pierson, Vocational Interests of Agriculture Extension, an unpublished Ph.D. thesis, Michigan State University, 1951.

The analysis of acquired characteristics of individuals or concentrated efforts at the "psychological environmental" 3/ level, though a preferable approach to the analysis of human behavior and for prediction purposes, have not been fruitful for agricultural occupations. The alternative analysis at a more "sociological environmental" 4/ level provides the base for this study of the human factor in farming. The latter

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3/ "Psychological Environment" referred to is that discussed by E. J. Asher, J. Tiffer, and F. B. Knight, Introduction to General Psychology, D. C. Heath and Company, 1953, page 102..."Those conditions with which the individual interacts...

as opposed to all those conditions which might affect an individual and which presumably exist when no organism is present".

4/ The "sociological environment approach" referred to is that considered by D. M. Michael, "The Social Environment", J. Oper. Res., 1959, Volume 7, Number 4, pages 506 to 523; in "the social environment is the separate contributions of four directive and formative agencies; namely, the individual; the culture in which he lives; the social groups with which he is associated; and the institutional world".

Biographical information represents the intimate story of individual development in such an environment and as such is less exacting than if only those conditions which affected the individual and those to which he responded or interacted were considered.

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approach using biographical information of individuals has, in itself, been used extensively in various industries and with satisfactory results in most cases. 5/ In agriculture,

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5/ Use of biographical information to reduce turnover in salesmen is reported by A. K. Kurtz, "Selecting Salesmen by Personal History Items", Psychology Bulletin 36, 1939, page 528; A. O. Ohmann, "A Report of Research on the Selection of Salesmen at the Tremco Manufacturing Company", J. Appl. Psychology, 25, 1941, pages 30 to 40. Other interesting results of J. G. Jenkins, "Prediction of Flight Training Performance by Biographical Data", J. Aviat. Med., 15, 1944, pages 131 to 135; A. W. Kerr and H. L. Martin, "Predicting of Job Success From the Application Blank", J. Appl. Psychology, 33, 1949, pages 442 to 444; N. Freedman and J. E. McCormick, "A Study of Personal Data as Predictors of the Job Behavior of Telephone Operators", Proc. Ind. Academy Sciences, 62, 1952, page 293 (Abstract).

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considerable difficulty was encountered with this approach due to problems in obtainance of nonconflicting prediction data on the subjects, developing criteria of success, and using both on an empirical, non-biased basis to test the various hypotheses. McCormick, Blanchard, and Thomas 6/ overcame this hurdle with considerable success by examing biographical data of farm tenants with professional farm management services and by using ratings of these tenants by professional farm managers as success criterion.

6/ McCormick, op. cit.

Management abilities as found in these farm tenants may differ from those in owner

operator farmers. However, an analysis of biographical information that differentiates between above and below average tenants is considered to be useful data in the search for those basic abilities which characterize a farm manager and which explain his behavior. The isolation of required abilities for successful farm performance and the measurement of individual abilities have many implications in agriculture.

Procedure

Although the isolation of basic abilities important to successful farming is stymied by the absence of a complete human behavior theory, by the imprecise nature of basic abilities, and by the restrictions imposed on empirical analysis by available statistical techniques, the procedure which follows is felt to have considerable merit as an alternative approach to the prediction of human behavior and occupational adjustment. What is needed for the analysis is: a. a body of logistic data from which abilities can be derived, b. criteria of levels of performance of farm tenants, c. some models or techniques for deriving basic abilities, d. a technique for measuring amounts of abilities possessed by individuals, and e. for estimating the relationships of abilities to criteria.

Biographical data of farm tenants from the McCormick, Blanchard, and Thomas study were used as the external manifestations of abilities. Such data were obtained from a tenant questionnaire of 105 multiple-choice and continous questions and from a tenant-wife questionnaire of 65 questions. Both questionnaires covered such subjects as: educational experience, childhood experience, family background, boyhood and girlhood farm experience, financial situation, health, armed service experience, recreational activities, cooperation of wife, and previous farming experience. The basis for these subjects representing external manifestations of required abilities was the result of research in this area by many workers over the years. A total of 34 biographical items on 453 subjects in the sample were found to differentiate significantly between above and below average tenants. From these biographical items were derived indices for the purpose of measuring tenant ability. 7/ The "Composite Index", 8/ was used as the prime criterion

for tenant ability 9/ in this study.

7/ Procurement of data, tests of significance of biographical items, and derivation of the "Composite Index" was accomplished in the study by McCormick, Blanchard, and Thomas, op. cit.

8/ Blanchard's hypothesized model for obtaining a prediction instrument for tenant ability from biographical data was that the level of performance of tenants is a function of the tenant's test score, the wife's score, and the interaction of the two. However, the wife's test score did not differentiate significantly between levels of performance, hence the model for the composite index is: "Composite Index" = f ("tenant index" + "team score").

9/ Note that the term "tenant ability" rather than "managerial ability" is used. This is because the authors are not confident that the measures of the human factor as developed by Blanchard measure precisely what is understood to be management by the economic profession. This does not invalidate the conceptual and statistical models used in this study for situations where one can truly speak of management.

Estimation Models

Factor Analysis:

The method of multiple factor analysis would appear to offer a systematic way of finding a few clusters of abilities in biographical data of farm tenants. The range of phenomena to be represented in the factor analysis domain is biographical characteristics of farm tenants as discussed earlier. No promising hypothesis is available regarding the processes that underlie these individual differences, thereby the domain is represented in terms of a set of measurements or criteria of managerial ability in the hope that the analysis reveals an underlying order of great assistance in eventually formulating scientific concepts covering the domain.

The application of this type of analysis to this problem is felt to have considerable merit in that basic and fruitful concepts are essentially lacking and crucial experiments have been difficult to conceive. It is appreciated that factor analysis by itself can only be a crude instrument, but with scientific intuition and sufficient ingenuity the factorial map of this new domain may enable one to proceed beyond the exploratory factorial stage to the more direct forms of psychological experimentation.

If, as hypothesized above, biographical data can be used as external manifestations of factors, then those biographical items which are manifestations of the same factor will have a tendency to appear together. In statistical terms, these items should be correlated. Thus "factor analysis" should be a useful technique in determining which items are correlated and to determine the number of factors represented by a large number of human attributes.

Let F_1, $F_2 \ldots F_m$ represent m factors any of which may be present in some or all (but at least two) of the observed items; let S_1 represent a factor present in item i; let E_i represent an error factor (error of measurement in variable i); then the "factor analysis model" in standard score form becomes:

$Z_i = a_{i_1} F_1 + \ldots + a_{i_m} F_m + b_i S_i + c_i E_i$, where Z is the standard score on item i.

The coefficients $a_{i_1}, a_{i_2} \ldots a_{i_m}$ are the "factor loadings" for item i, and the factor analysis problem is to find estimates of the a's. This also involves the determination of how many factors are required. 10/

10/ For computing procedures see A. C. Holzinger and H. H. Harman, Factor Analysis, University of Chicago Press, 1941; L. L. Thurstone, Multiple Factor Analysis, University of Chicago Press, 1947.

Factor Scoring:

Having determined the number of factors represented by a large number of biographical items, it is necessary to measure the factor amounts possessed by individuals before the type and the degree of the relationship between tenant ability and the factors can be specified. Determining individual factor scores could be accomplished if the relationship between the F_j's and X_i's were known. To estimate such a relationship using ordinary regression techniques is not a simple matter, since the F_j's cannot be observed; and it is consequently not possible to construct correlation coefficients between the F_j's and any of the X_i's. However, it is possible to treat the factor loadings from the factor

analysis as the correlation coefficients of the items with the factor, so that the following "factor scoring model" can be employed:

$F_j = \sum_{i=1}^{n} \beta_i X_i + E_j$, where F = score on factor j, β_i = partial regression coefficient of F_j on X_i, X_i = response to item i, influencing the factor j, E_j = random error, and where j = (1...m), and i = (1...n).

Prediction Model for Tenant Ability:

Having determined the amount of each factor present in each individual, the type and degree of relationship between tenant ability and factors can now be estimated by using the following model:

$M = \beta_0 + \beta_1 F_1 \ldots \beta_m F_m + E$, where M = level of tenant ability as expressed by the "Composite Index", β_j = partial regression coefficient of M on F_j, F_j = factor j, and E = random error.

Results

Following the procedure described above, six factors were isolated from the 34 biographical items, explaining 83 per cent of the overestimated total variance to be explained by all items. From the factor loadings of items on the various factors and the items themselves, each factor appeared as an interpretable functional entity representing abilities and motivation important to farm firm organization and operation. Names and interpretations given to the factors are:

Socio-economic status (F_1), referring to individual satisfaction abilities and attributes which result in enjoyment and demonstration of achieved material success.

Prior farm management success (F_2), as indicative of associative learning and habit formation abilities.

Farm family inter-personal relations (F_3), a personality factor associated with abilities and motivations as developed in the environment of relatively large and dynamic commercial farms.

Family farm inter-personal relations (F_4), a factor referring to abilities developed

in the traditional social and cultural environment of small family farms.

Education (F_5), as concerned with knowledge and learning abilities in a broad sense and related to occupational application.

Job mobility (F_6) ("job frustration"), associated with horizontal job movement and creative instability.

The factor scoring equations employed to estimate the amount of each factor present in each of the individuals included between two and fourteen different items as the independent variables (Appendix Tables 1 and 2). The resulting estimation equation for tenant ability with factors as the independent variables took the following form: 11/ 12/

$$M = 51.91 + .20F_5^2 - .99F_6 + .04F_1 F_3 - .11F_4^2 - .95F_5 + .70F_4.$$

11/ $R^2 = .511$ and is significant at $\alpha = .01$. The "Wherry-Doolittle Variable Selection Method" was employed to select the combination and form of factors giving the best prediction (see Appendix Table 3 for steps in variable selection).

12/ An M (Composite Score) of 50 represents median tenant ability. For more details on the composite score see McCormick, Blanchard, and Thomas, op. cit.

This estimation equation for tenant ability indicates that the most important factors influencing this ability are education (F_5), job mobility (F_6), "family-farm" interpersonal relations (F_4), in this order. This order of importance of factors is consistent with the relationships found between factors and other subjective and objective measures of tenant ability; namely, "net returns per acre", "tenant index", and "team score". 13/

13/ Presentation of the empirical results for these ability criteria has been omitted from this report for the sake of brevity and clarity of presentation.

Implications and Conclusions

Results from this research indicate that biographical data can, in fact, measure basic abilities and motivations relevant in studies of the human factor in agriculture.

Questionnaires which are designed to predict managerial ability on the basis of biographical data will, of course, always be ephemeral in character. But this research also suggests that a procedure such as the one used can aid in the isolation of basic factors which are considerably more general than biographical data. Such an isolation of basic factors should be helpful in designing measures of management of more analytical value than biographical data.

The results from this research also suggest that a research approach to understanding and manipulating management will likely be more successful if the approach is broader than economics and inclusive of all social sciences. The importance to management of such factors as education in its broadest sense, job mobility, socio-economic status, and personality factors indicates that management ability may be influenced by the entire human nature and its environment to a considerably larger extent than is frequently expected. The importance of continued development of theories on values, behavior, and learning cannot be overstated in the search for understanding management in agriculture.

It is encouraging that education was found to be the most important positive factor because it suggests that tenant ability (and by inference management) can be improved through increased education. However, the question is more involved, since the factor "education" as determined by factor analysis is considerably broader than formal education. This factor implies presence of motivation to learn and to look for ideas, and knowledge about how to instill such motivations is considerably less than our assumed ability to confer formal education. Thus, the factor "education" is considerably more difficult to manipulate than might appear at first glance. The same applies to a more or lesser degree to other factors. It appears that all factors can be manipulated, but specific suggestions on how to change factors and the consequences of such change as related to managerial ability and other adjustments must await further research, above all in the area of human behavior and learning.

Appendix Table 1 Items and Coefficients of Factor Scoring Equations

Factors	Items and Regression Coefficients Associated with Items														R^2 Value
F_1	X_{30}	X_{31}													.8141*
	5.26	4.74													
F_2	X_{10}	X_{11}	X_{17}	X_{18}	X_{19}	X_{21}	X_{22}	X_{23}							.5033*
	1.04	1.82	.41	1.19	.85	1.58	1.55	1.56							
F_3	X_9	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{20}								.6674*
	.45	2.09	2.56	.98	.73	2.61	.58								
F_4	X_4	X_5	X_7	X_{12}	X_{14}	X_{15}	X_{23}	X_{25}							.6363*
	.61	.73	.38	.75	2.91	2.84	1.39	.39							
F_5	X_1	X_2	X_4	X_5	X_7	X_{10}	X_{12}	X_{21}	X_{23}	X_{25}	X_{27}	X_{28}	X_{29}	X_{34}	.5634*
	1.48	.44	.40	.36	.75	.68	.41	.61	1.41	.63	.89	.74	.86	.34	
F_6	X_4	X_5	X_{12}	X_{17}	X_{18}	X_{21}	X_{23}	X_{24}	X_{26}	X_{28}	X_{33}				.6199*
	.31	.50	.28	1.44	.88	.29	1.09	1.64	2.13	.81	.63				

* significant at α = .01

Appendix Table 2 Description of Attributes Used in the Analysis

Item	Description 1/
1	Both he and wife graduated from high school
2	Has same or more education than brothers and sisters
4	Liked best more than one school subject
5	Did not change schools more than once
7	He and/or wife attended a high school of less than 99 pupils
9	Either he or wife has one or more older brother or sister while the other has one or none
10	Enjoyed team sports while wife did not
11	Both lived on a farm during childhood of 120 acres or larger
13	During childhood, parents gave him "spending money" When he need it; while wife received an allowance or another form of renumeration
14	His and/or wife's father was an owner operator
15	His and/or wife's father was a farm tenant
16	Both fathers had farm experience
17	If operated a farm, never took part-time non-farm jobs during slack periods
18	If operated a farm, it was 120 acres or larger in size
19	Was married and had no children
29	Health was good to excellent

1/ Each item refers to experiences and information prior to operating present farm. The items as listed refer to those characteristics which differentiated between success groups in an earlier study. These items when used in factor scoring are in some instances reverse coded and in others similar to the above listings, e.g., item 28 when scored as above increases the individual's score on F_5 whereas the score on F_6 is increased when the item is reversed or the individual had not held an office in some organization.

Appendix Table 2, continued

Item	Description
21	If rented a farm, operated it three or more years
22	Owned farm machinery without a mortgage
23	Had farm experience of 0 to 9 years as a paid farm hand
24	Had 0 to 1 different types of non-farm work during the previous ten years
25	Carried accident, health, and/or hospital insurance
26	Did not have an income over $2,000 per year from off-farm sources
27	Held office in a local church organization
28	Held office in one of a complex of organizations, while wife never held office
30	If owned a T. V., generally watched comedy shows and plays rather than other T. V. programs
31	Did not have a T. V.
33	He and wife did not have horseback riding as a hobby
34	Had taken more than one vacation of at least one week or more away from home during prior five years

Appendix Table 3 Variable Selection 1/ for Regression of "Composite Index" on Factors

Steps	Variables Selected	R^2 Value
1	F_5^2	
2	F_5^2, F_6	.422**
3	F_5^2, F_6, $F_1 F_3$	.476**
4	F_5^2, F_6, $F_1 F_3$, F_4^2	.493**
5	F_5^2, F_6, $F_1 F_3$, F_4^2, F_5	.505**
6	F_5^2, F_6, $F_1 F_3$, F_4^2, F_5, F_4	.511**

** Significant from zero at the one per cent probability level 2/

** Significantly larger at the one per cent probability level than the preceding sub-set with one fewer variables

1/ For the test used in testing the hypothesis that the R^2 calculated for each of the six stages of selection differed significantly from zero, see G. W. Snedecor, Statistical Methods Applied to Experiements in Agriculture and Biology (Fourth edition), Iowa State College Press, Ames, 1948, pages 340 to 351.

2/ The statistical significance test in this analysis was:

$$F_{(k-m,\ n-k-1)} = \frac{(R^2_k - R^2_m)\ /k-m}{(1-R^2_k)\ /n-k-1}$$

This formula was taken with a slight change in notation from Q. McNemar, Psychological Statistics, J. Wiley and Sons, Inc., New York, 1949, page 266. For further reference to statistical tests used in conjunction with the "Wherry-Doolittle Variable Selection Method", see A. Summerfield and A. Lubin, "A Square Root Method of Selecting a Minimum Set of Variables in Multiple Regression", Psychometrica, Volume 16, Number 3, September 1951, pages 271 to 284 and 425 to 437.